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OLR BACKGROUNDER: AUTONOMOUS VEHICLES

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ISSUE

This report provides answers to several questions about autonomous vehicles (AVs), which are generally defined as vehicles with the capacity to self-drive without being actively controlled or monitored by a human operator. Unless otherwise noted, the information in this report comes from *Autonomous Vehicle Technology*: A Guide for Policymakers, 2014 report from RAND Corporation's Transportation, Space, and Technology Program.

WHY IS AV TECHNOLOGY IMPORTANT NOW?

Although AVs may seem futuristic, the reality is that the technology that makes it possible for vehicles to operate without a driver is very close to maturity and commercial introduction. Every major automaker is engaged in research in this area, and AVs are predicted to be commercially available in five to 20 years. AVs will have a profound impact on society and will require policymakers to examine, modify, and create laws to maximize benefits of this technology to society while minimizing its costs.

Although AVs are not yet available commercially, many cars currently on the market have some degree of automation to assist and make decisions for a human driver, such as crash warning systems, adaptive cruise control (ACC) (which automatically adjusts the vehicle speed to maintain a safe distance from the vehicle ahead), lane keeping systems, and self-parking technology. This gradual introduction of automated technology has created a continuum between human-operated vehicles and AVs (see below). This means that some policy questions regarding AVs may need to be answered now, and some states have already done so.

Finally, because AV technology has great potential to positively impact society, researchers at RAND suggest that policymakers should be aware of the effects of exiting policy (or lack thereof) on the development and adoption of this technology.

Historically, automakers have been reluctant to adopt costly technology, even if it substantially improves safety, and policymakers may need to consider how to negotiate risks to reach opportunities.

HOW WILL THIS TECHNOLOGY ARRIVE TO MARKET?

The transition to AVs will be gradual as automakers incorporate technology that allows for varying degrees of automation into their vehicles. This creates a continuum of automation among vehicles on the road, which the National Highway Traffic Safety Administration (NHTSA) classifies using a five-level hierarchy:

- Level 0: the human driver is in complete control of all functions of the car
- Level 1: one function is automated
- Level 2: more than one function is automated at the same time (e.g., steering and acceleration), but the driver must remain constantly attentive
- Level 3: driving functions are sufficiently automated (generally under specific driving conditions) that the driver can safely engage in other activities
- Level 4: the car can drive itself without a human driver

Industry experts believe that, because of some technological challenges described below, the first commercially available AVs will use a "shared driving" concept of operation (or NHTSA Level 3). At that level, the vehicle will drive autonomously under certain conditions (e.g., below a certain speed or only on certain roads) and will revert to manual driving outside of those conditions. Shared driving will require vehicles and humans to effectively work together, and humans will need to be able to effectively reengage and drive the vehicle when required.

HOW DO AVS WORK?

In general, AVs use a "sense-plan-act" design. AVs use a variety of sensors (including lidar (light detection and ranging), radar, cameras, and infrared) that complement each other and make up for weaknesses in any one type of sensor. Software algorithms interpret sensor data (e.g., lane markers from images of the road), to make decisions about the vehicle's actions. These decisions are then translated into commands to the vehicle's control systems (e.g., steering and braking). AVs also use global positioning systems (GPS) and inertial navigation systems (INS) for directions and identifying location. Many AVs now in development can sense, plan, and act in many circumstances, but researchers are still working on developing a system that performs these functions consistently and reliably, in complex driving environments, and with robust backup systems should a component fail.

AV developers have suggested an alternative to an elaborate sensing system: vehicle to vehicle (V2V) and vehicle to infrastructure (V2I) communication. These would allow vehicles to communicate with each other and infrastructure to understand their environment (e.g., receive information about icy conditions) and coordinate their behavior (e.g., maintaining faster speed and closer spacing on highways). V2V and V2I communication technologies are not necessarily required for AVs to function on the road (in fact, integrating cars with V2V communication with conventional vehicles may present a significant challenge) and pose potential public cost and cybersecurity concerns, but have the potential to improve an AV's ability to operate in complex driving environments.

WHAT ARE THE POTENTIAL BENEFITS AND COSTS OF AVS?

The potential benefits of AVs are profound but will not come without costs. The list of potential benefits and costs included below is broad and not exhaustive, and each of these benefits and costs may be realized at different levels of automation.

Benefits:

- Dramatic reduction in car crash frequency, as well as the private and social costs associated with car crashes (e.g., lives lost, hospital stays, property damage, congestion, and high insurance premiums)

- Increased mobility for those who cannot drive (e.g., elderly or disabled people), and therefore an increase in their independence and ability to access services

- Increased vehicle throughput (or the amount of vehicles that get through a certain section of highway in a given time) because AVs can travel at higher speeds, follow more closely, merge efficiently, and avoid exaggerated braking and accelerating behaviors that cause stop-and-go traffic

- Decreased time costs of driving and increased productivity because vehicle occupants can engage in other tasks

- Improvements in fuel economy, as AVs will drive more efficiently than a human driver and can be made lighter due to lower crash risk

Costs:

- Decreased time costs of driving may encourage people to drive more frequently and longer distance, potentially increasing congestion, vehicle miles traveled, and fuel consumption

- Making driving more convenient may also discourage use of, and divert funding from, public transit systems, which are an important resource for (1) low-income individuals and (2) reducing vehicle congestion and emissions

- Governments may lose revenue from things like traffic tickets or parking fees (as nearby parking may be unnecessary)

- Job losses because human drivers become unnecessary

- The expected decline in crashes could negatively impact certain industries, such as insurance companies and body shops

HAVE OTHER STATES PASSED LEGSILATION TO ADDRESS AVS?

Although it is not clear that legislation is necessary to permit testing or operation of AVs, four states (Nevada, Florida, California, and Michigan) and the District of Columbia (D.C.) have passed legislation regarding AV testing and development (Nev. Rev. Stat. Ann § 482-A; Fla. Stat. § 316.86; Cal. Veh. Code § 16-6; Mich. 2013 PA 231; D.C. Code § 50-2352). These laws include provisions regarding AV component requirements, operator requirements, liability, and insurance. They also require their state motor vehicle or transportation department to develop regulations for or a report on AV testing and operation.

In general, the enacted laws define AVs as vehicles with the capacity to self-drive without being monitored or controlled by a human (driver assist technologies, such as crash avoidance technology, are explicitly excluded from the definition of AV). They define an AV operator as the person who engages the autonomous technology, whether or not the person is in the vehicle as it drives, holding the operator accountable for any of an AV's actions that violate traffic and other applicable laws.

Nevada, Florida, California, and D.C. require AVs to have a means of engaging and disengaging the technology and a system to alert the operator if a component fails. Thus, all but Michigan explicitly require a human in the vehicle to take control of the vehicle if necessary.

Additionally, Nevada, Florida, Michigan, and DC exempt the original manufacturer from liability if a third party converted the car to an AV. Three states (Nevada, Florida, and California) require researchers or companies testing AVs to obtain additional insurance coverage (e.g., Florida and California require AV testers to obtain an instrument of insurance, surety bond, or proof of self-insurance in the amount of $5 million).

Although these laws are generally intended to address AV testing, Nevada has also taken steps to regulate the individual operation of commercial AVs. By law, before an AV can be sold in Nevada, the AV manufacturer or a licensed third party must issue a certificate of compliance for the automated technology installed on the AV. The certificate of compliance must state that the AV is equipped with a mechanism to engage and disengage the autonomous technology and a system to warn the vehicle occupant if a technology failure occurs. Nevada regulations also require a license endorsement to operate an AV.

A number of other states have introduced AV-related legislation, much of which is similar to legislation enacted by other states. At this time, NHTSA does not recommend that states authorize the operation of AVs for purposes other than testing.

WHAT POLICY QUESTIONS DO AVS RAISE?

As research continues on AVs and they get closer to entering the market, policymakers at the state and federal levels will have to consider many different policy questions. To tackle these issues effectively, RAND suggests a guiding principle for policy makers: "AV technology should be permitted and encouraged if and when it is superior to average human drivers."

Possibly the biggest challenge for policymakers will be regulating AV technology. As RAND notes, "vehicle performance is traditionally tested at the federal level by NHTSA, and driver performance is tested at the state level by motor vehicle departments. AVs—in which the driver is the vehicle—complicate these traditional roles."

AV technology is developing rapidly and industry groups are working to develop engineering standards (which are developed by the technology community and adopted voluntarily by industries for consistency) for AVs. The federal government and states may choose to adopt regulations regarding AV technology at some point, but RAND suggests that it may be easier to make effective regulations if policymakers wait until AV technology matures rather than attempting to keep up with rapid advancement. RAND also suggests that states may want to defer to

NHTSA (which develops the Federal Motor Vehicle Safety Standards) in regulating AVs or work to develop model legislation to avoid a patchwork that may cause significant barriers to manufacturers in the development and deployment of AVs.

AVs are also likely to prompt policy questions that go far past the regulation of AV technology. Below, we provide a sampling of AV-related issues that may need to be considered by states.

- ***AV testing:*** Should the state take steps, if it has not already done so, to regulate AV testing within its borders?

- ***Driver qualifications:*** How should the state test and license AV operators (or is it necessary)? Who should be permitted to operate an AV—for example, can an operator be blind, intoxicated, or under the age of 16?

- ***Technology adoption incentives:*** AVs have the potential to cause market failure because the person who purchases the AV incurs some benefits, but many of the benefits are incurred by society as a whole (positive externalities). For example, a person may individually benefit from a lower car crash risk, but the cumulative benefit of this lowered risk to society is much larger. As they exist currently, AVs are several times more expensive than conventional vehicles, and the cost is unlikely to go down unless demand is high and manufacturers can take advantage of economies of scale. However, because individuals do not receive the full benefit of AVs, high cost, as well as a general public distrust of technology, may discourage the public from adopting this technology. Should the state, knowing the risk of market failure, intervene? If yes, how can it effectively encourage adoption of AV technology?

- ***Liability and insurance:*** Who is responsible when an AV crashes (manufacturer or operator)? Should researchers be required to hold additional insurance when testing AVs? Should states adopt a no-fault system of liability, under which accident victims are directly compensated for their losses through their own insurance policy? Should the law assign liability to the manufacturers if the vehicle malfunctions?

- ***Distracted driving:*** Should the state update distracted driving laws to (1) allow for the development of vehicle communication systems and (2) allow AV operators to engage in other tasks while the vehicle is in operation?

- ***Data use and privacy:*** How long can data recorded by AVs be stored and who should be allowed to view it? Should laws be created to protect data or specifically prohibit potential software hacking?

- ***Highway Signage:*** Should the state require strict conformance to signage and marking standards to make it easier for AVs to process difficult routes or road conditions (for instance, requiring construction zones to be signed in a universal way)?

HOW CAN I LEARN MORE?

In addition to the RAND report previously mentioned (which is available at http://www.rand.org/pubs/research_reports/RR443-1.html), those interested in learning more can consult the following sources:

Preliminary Statement of Policy Concerning Autonomous Vehicles, NHTSA, 2013

This policy statement includes NHTSA's AV-related research plans (such as research on human-technology interactions) and recommendations to states for developing AV policy. It is available here:
http://www.nhtsa.gov/About+NHTSA/Press+Releases/U.S.+Department+of+Transportation+Releases+Policy+on+Automated+Vehicle+Development

Autonomous Vehicle Legislation, Council of State Governments

This brief discusses and analyzes autonomous vehicle laws passed or introduced as of March 2014 and provides states with policy recommendations. Read it here:
http://knowledgecenter.csg.org/kc/content/autonomous-vehicle-legislation

Automated Driving: Legislative and Regulatory Action, Center for Internet and Society

This page tracks legislative and regulatory changes related to AVs, including bills in other states that have not passed. It is available here:
http://cyberlaw.stanford.edu/wiki/index.php/Automated_Driving:_Legislative_and_Regulatory_Action

Sue My Car Not Me: Products Liability and Accidents Involving Autonomous Vehicles, by Jeffery K. Gurney

This report discusses issues with AVs related to liability and insurance coverage. It is available here: http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2352108

Driverless Vehicles? Even in DC Streets? An Autonomous Vehicle Takes a Capitol Test Run, Washington Post, 2014

This article describes a ride in Carnegie Mellon University's driverless car, which is considered to be one of the most advanced in the world. It also has a video of the demonstration. See it here: http://www.washingtonpost.com/local/trafficandcommuting/driverless-vehicles-even-in-dc-streets-an-autonomous-car-takes-a-capitol-test-run/2014/08/25/6d26baa8-06a4-11e4-8a6a-19355c7e870a_story.html

Driverless Cars are Further Away than you Think, MIT Technology Review, 2013

This article offers an overview of the technological challenges faced by AV developers. Read it here: http://www.technologyreview.com/featuredstory/520431/driverless-cars-are-further-away-than-you-think/

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